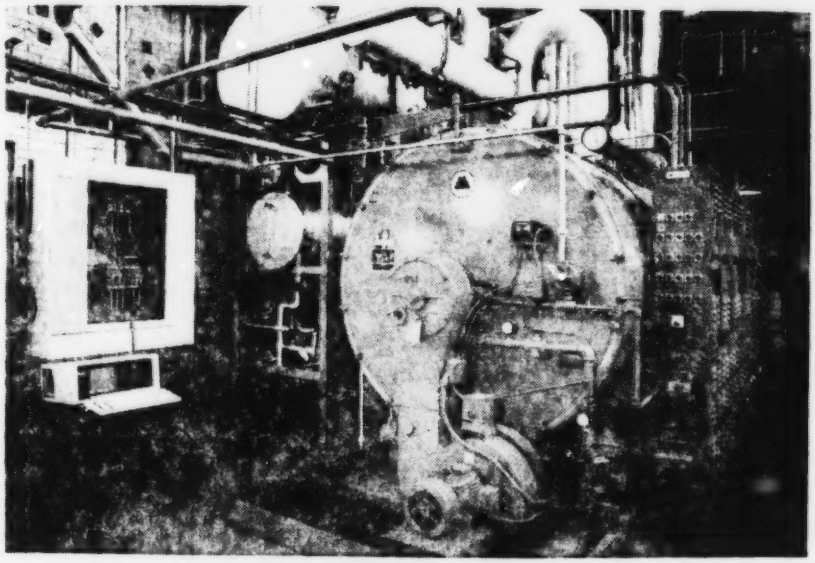
Bristol Aerospace Limited

Dual-Fired Energy Efficient Boiler System

Final Report March 1988



bristol aerospace limited

Manitoba Energy and Mines

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1.0 Executive Summary

Under the Enerdemo-Canada Program, Bristol Aerospace Ltd. received funding to offset a portion of the project costs, for a novel boiler system. This system, referred to as a "Dual Fired Gas/Electric Boiler System" was designed by Bristol Aerospace in conjunction with Volcano Inc., a Canadian boiler manufacturer.

The boiler system is controlled by a computer which monitors the plants electrical demand. The boilers operate on electricity at the off-peak rate. When electrical demand reaches a predetermined setpoint, the system switches over to natural gas. The system is fail-safe, in that the gas train can operate outside the control system. In the event of a computer failure, steam is still generated.

The system is ideally suited for an operation which has a large peak usage of electricity, and still requires heat during the off-peak period. This type of gas/electric system is only appropriate within areas that have gas and electrical rate structures which will produce an acceptable payback.

This report describes the boiler system and details the performance of the system during 1987. The project cost Bristol $500,305 after funding and is showing a yearly saving of $134,660. This equates to a payback of 3.71 years. The project cost including funding assistance (excluding monitoring and information transfer costs) totalled $643,305, which calculates out to a payback of 4.77 years.

The original proposal showed an estimated Bristol cost of $428,000 with a payback of 2.3 years. A contributing factor to this difference in savings has been the addition of 86,000 sq. feet to the facility and its impact to the plant electric demand curve and heat distribution.

Overall, this project is considered a success, both technically and financially. It is expected that significant savings will be continued over the projected 20 to 25 year life of the system.

1.1 Resume Executif

Dans le cadre du programme Enerdemo-Canada, une subvention, pour compenser en partie les coûts en capital d'un système original de chaudière, à été offert à Bristol Aerospace Ltd. qui, avec Volcano Inc, un fabricant canadien de chaudières, a élaboré le système nommé "Système de chaudière à énergie double gaz/électricité".

Un ordinateur vérifie la demande, en électricité, de l'usine et contrôle le système de chaudiére qui fonctionne par électricité au tarif des heures creuses. Lorsque un point prédéterminé est atteint par la demande en électricité, le systéme se transfert au gaz naturel. Le systéme est indéréglable car le train d'engrenage du gaz fonctionne indépendament du systéme de contrôle. La vapeur continue a être produite même en cas de panne de l'ordinateur.

Ce système est idéale dans une industrie qui a des pointes en électricité très élevées mais qui exige de la chaleur dans les heures creuses. Ce genre de système gaz/électricité ne doit être utilisé que dans un endroit où les tarifs de gaz et d'électricité permetteront une récupération acceptable.

La description de ce système et les détails de son rendement au cours de 1987 sont présentés dans ce rapport. Suite à la subvention le coût du projet, pour Bristol, s'est élevé à 500 305$ et indique un bénéfice annuel de 134 660$ ce qui représente une récupération en 3,7 ans. Le coût du projet y compris la suvention (mais sans compter les coûts de vérification et de transfertd'information) s'est élevé â 643 305$ qui représente une récupération en 4,77 ans.

Le projet, au début, indiquait un coût approximatif pour Bristol de 428 000$ avec une récupération en 2,3 ans. L'incorporation de 86 000 pieds carré â l'usine et son impacte sur la courbe de demande en électricité et en distribution de chaleur est la raison principale de cet écart en bénéfices.

Techniquement et financièrment ce projet s'est avéré un succès. D'importants bénéfices sont prévues au cours des 20 à 25 ans de vie du système.

2.0 Enerdemo - Canada Program

In 1984, Energy Mines and Resources Canada allocated more than $80 million to finance a nation wide conservation and alternative energy demonstration program - ENERDEMO Canada. Many provincial governments including the Manitoba Department of Energy and Mines entered into cost-shared agreements with the Federal government in support of the Enerdemo program. This meant that for the full five year term, both the Federal and Provincial governments agreed to cost-share regionally appropriate demonstration programs which met the required criteria.

The objectives of Enerdemo were two-fold:

1. To accelerate, through demonstrations, the adoption and commercialization of energy conservation, oil substitution and alternative energy technologies.

2. To create business opportunities and employment in new or existing industries.

The size of projects eligible for Enerdemo vary from large to small, however all projects have to demonstrate the advantages of using new conservation and alternative energy techniques or systems. All projects have to have good potential for widespread adoption without further funding assistance.

Bristol Aerospace has long been committed to an aggressive policy of energy conservation and management. The corporate motivation for accessing Enerdemo was focused on increasing efficiency, improving productivity and overall operational savings.

This Bristol Aerospace Enerdemo project was initiated with a proposal dated October 1984. Funding for this project was approved March 7, 1985.

Funding for the Bristol Aerospace Dual-Fired Energy Efficient Boiler System project was portioned as follows:

Energy Mines & Resorces Canada	$ 87,500	(14.0%)
Manitoba Energy & Mines	$ 87,500	(14.0%)
Volcano Incorporated	$ 22,000	(3.5%)
Bristol Aerospace Limited	$428,000	(68.5%)
	$625,000	(100%)

Note: Bristol's contribution increased from $428,000 to $500,305 due to unforeseen capital costs, required for full commissioning. The overall project cost was therefore $697,305.

3.0 Introduction and Overview

In the summer of 1985, Bristol Aerospace Ltd. installed a dual-fired natural gas/electric boiler system in its Winnipeg plant. This installation enabled Bristol to use off-peak electricity to produce heating and process steam.

Previous to the installation, the plant had an average electrical load factor of 30 - 40%, due to the daytime electrical manufacturing requirements. It was recognized that if this load factor were increased to 100%, the electrical requirements would have only a consumption cost without a demand penalty. Analysis confirmed that this demand free electricity would be cheaper, per unit of energy, than the alternatives, natural gas or bunker C oil. It was therefore concluded that it would be more economical for Bristol to use electricity to produce steam during the off - peak period instead of natural gas or bunker C oil.

The dual-fired boiler unit was purchased from Volcano Inc. of Sherbrooke, Quebec and has a control system based on a Westinghouse Numalogic Programmable Controller (PLC). Installation was carried out by Four Seasons Contractors, and the Winnipeg plant Engineering Department of Bristol Aerospace Ltd. under the direction of J. Pastula.

The boiler system is capable of increasing the plant electric load factor from an average of 30 - 40 % to as high as 90% in the winter months. This is done through a master PLC

system which monitors the electric meter. When the electrical demand falls below a preset maximum, electrical elements within the boilers are activated until either the maximum demand is reached or the steam requirement is maintained.

The cost of this project was $697,305. Assistance was obtained from the Federal Department of Energy Mines and Resources Canada and Manitoba Department of Energy and Mines with matching contributions of $87,500. Government funding was made available under the Manitoba/Canada Conservation and Renewable Energy Demonstration Program - Enerdemo. Volcano Inc. contributed $22,000 leaving Bristol Aerospace Ltd. to fund the remaining $500,305.

4.0 Background

Bristol Aerospace of Winnipeg has long been committed to an aggressive policy of energy conservation. Bristol supports the Federal Government's goal of Canada achieving self-sufficiency through improved technology and a more prudent use of our energy resources. At the corporate level, Bristol's concerns are directly focused on increased efficiency, improved productivity and overall operational savings.

In 1980 in co-operation with the Manitoba Department of Energy and Mines, Conservation and Renewable Energy Branch, Bristol undertook a thorough analysis of energy usage at their Winnipeg plant.

As a result of these findings, some 14 projects, encompassing structural and mechanical improvements, were undertaken. These energy management initiatives resulted in a reduction of energy costs of the Winnipeg plant by approximately $1.2 million over a six year period. As a direct result of this concentrated energy management effort, Bristol embarked on its most ambitious effort in 1984 - the installation of an entirely new dual-fired gas and electric boiler system, to replace the 60 year old boilers that were fed by bunker C oil and natural gas.

4.1 Previous Boiler System

Steam was supplied to the 500,000 square foot Winnipeg plant by two-280 HP Vulcan water tube boilers located at the Northeast corner of the complex (Figure A). Each boiler primarily burned interruptible natural gas with bunker C oil used as a backup.

To service this large area, steam was produced at high pressure. A separate 6" high-pressure line was installed to deliver heat directly to building #2 and #4, with minimal latent heat loss.

The steam is primarily used for plant environmental heating during the winter months. It is also required whenever the plant is operational, to heat process tanks and to steam-clean parts. Each boiler was rated to deliver steam at a pressure, as high as 100 psi, which led to the requirement of "continuous monitoring" by second class stationary engineers when the boilers were functioning. To meet the monitoring requirements the plant operated three shifts for seven days per week from September 16 to May 14, and two shifts for five days per week from May 15 to September 15. In July the plant shuts down for a two week period.

The plant environmental heating equipment includes unit heaters in the plant and radiators in the offices, all of which

operate with low pressure 15 psi steam. To deliver the heat requirements, the steam from the large service headers passed through pressure reducer valves, prior to entering the smaller distribution lines. The majority of process equipment also operated at 15 psi, with only a few coils sized to use high pressure steam where it was readily available.

The boilers were equipped with fully modulating damper controls to reduce the excess air in the combustion chamber, and thus increase the thermal efficiency. But, with the 60 year age of the boilers, the mortar between the firebrick had deteriorated creating high excess air problems during low load conditions. To tighten this brick work a costly overhaul was required, with no guarantee that the 80% efficiency of the new boilers could be achieved. To compound this problem, the steam required by the plant had steadily decreased during the past few years with the implementation of energy saving projects. This had led to low load conditions during a greater portion of the year, thus a lower average thermal efficiency.

The installation of an improved condensate return system in October 1983, improved the amount of return water from 35% to 75%. The only water being drained is that used by process equipment, where a chance exists that it may be contaminated. The remaining makeup water is supplied by air compressors located in the boiler room which elevate softened city water to 100 degrees fahrenheit prior to entering the boiler.

4.2 Electrical System

Electricity is supplied to the Winnipeg Plant via a 24,000 volt service line which passes through various on-site transformers, converting it to usable voltages. Usage is monitored by a pulse meter which reads a trickle current off the mainline. This meter reads the productive power (kilowatt-hours kWh) and the non-productive power consumer (kilovars reactive kVAR), which is wasted to produce magnetic delay to register the apparent or metered demand (kVA) of electricity for the plant. The ratio of productive power (kW) to apparent demand (kVA) at any moment in time is called the power factor.

A contract with Manitoba Hydro provides for monthly charges based on the total productive kWh consumed, and an additional charge for the highest metered kVA reading during the month. A penalty clause allows a minimum kVA charge during the year of 80% of the maximum reached during the previous winter months (Nov-Feb). The lowest cost per unit of electricity is reached by maintaining a constant demand during the month while maintaining a power factor of unity. This is defined as 1.0 load factor of 100% usage of available electricity. As the load factor decreases, the average electrical cost increases.

To reduce the non-productive power used, capacitors were installed in April, 1981. This reduced the apparent demand by 200 kVA during the highest demand period of the day. This equated to a .99 power factor or 99% usage of metered electricity.

The plant maintained only a 40% load factor for the month because of the high demand between 8:00 and 16:00 of a production day (Figures B2 & B3). This demand consisted of a continuous base load and an operational load. The base load (Figure B1) consists of heating and air conditioning equipment, exhaust fans, computer equipment, and continuously operating test and process equipment. The operating load is comprised of additional heating and air conditioning equipment, machinery, furnaces, lighting, car plugs, and additional exhaust fans. Since some of the equipment is used intermittently, the demand fluctuates during the day.

When a few large users require electricity at the same time, the demand reading can jump as much as 400 kVA from the norm. The problem was that some of these large users (i.e. furnaces) demand large amounts of electricity for short periods during a cycle, which cannot be interrupted. Therefore, it was difficult to schedule electrical requirements to eliminate coincidental usage.

5.0 Dual Boiler System

As shown in the electricity usage profile graphs (Figures B1-B3), the maximum electrical demand for the plant was maintained only between 8:00 and 16:00 of a production day. Improvements had been made to the scheduling of high electrical demand machines, but any large decrease in the demand could only be realized by using these machines during off-peak periods. This would prove to be disruptive to the manufacturing flow and also costly because of overtime.

Since the high demand was required, it was cost effective to use the electricity available during the off-peak periods of the day which was below the highest demand reading. The additional electricity is considered demand-cost free because it does not serve to increase the highest demand reading.

The most productive use of this electricity is through making steam because it is required during the off hours for environmental heating in the winter, as well as during operating hours for process equipment.

Using electricity to produce steam, required the installation of electric coils within new fire tube type boilers, which are suited for using electric immersion coils. With the new boilers, the gas efficiency increased to 80% under any load conditions. Combining this with the electrical efficiency led to a 90% overall boiler efficiency for the projected load.

The boilers were installed within the plant space, close to where the steam is required. This allowed the boiler pressure requirement to be reduced to 15 psi because the steam did not have to be transferred as far through the pipes. Low pressure is used, thus allowing conversion to "guarded status" which means,one 8-hour shift, per day, of monitoring, whenever the boilers are operating.

With the boilers located in the plant, the bunker C oil could not be used as backup fuel. This requires switching from interruptible to uninterruptible natural gas which costs more. But by eliminating the use of oil, the gas generated steam at 80% efficiency.

If electricity were used as the only energy source for the boilers, the demand could be maintained at 4000 kVA in January with 100% load factor (Figure C). By using this level of electricity during the winter months, Bristol would be required to pay for a demand of 3200 kVA (80% of 4000) for the reminder of the year. With an average peak demand of 2700 kVA historically required during the summer months (prior to building #7), and no process steam required during the off peak periods, the 3200 kVA demand in January will be set at 3400 kVA (2700 - 0.8). This level could be maintained from December to February but decreased to 3000 kVA in November and March when less heating is required.

The plant cannot maintain 100% usage of available electricity for the entire year. During the winter months, the

plant needs enough steam for environmental heating to maintain a 100% load factor. As the temperature gets warmer, the environmental heating load decreases until the maximum demand cannot be maintained during the off-peak hours (Figure D). When the plant is operating, the combination of plant machine load and boiler electric load will always maintain the maximum demand.

5.1 Control System

The boiler control system combines a Westinghouse Numalogic Programmable Controller (PC) with Honeywell PID Controllers. One of the prerequisites with the system was to be sure that there could not be complete failure in the heating system. To accomplish this, Bristol purchased boilers that operated on gas without any additional outside control systems. Therefore, if there is a failure with the main control system, the Honeywell PID controller will automatically maintain the gas train operations and produce the required steam.

The control of the electric element is done through the programmable controller located at each boiler. These work in a "master-slave" relationship, whereby one monitors the demand meter, calculates the available electricity and then distributes it to each boiler. These controllers also monitor the various alarms on the boilers so that a problem is immediately annunciated.

The electrical demand is continuously monitored, but the boilers are adjusted every 20 seconds to allow for modulation around a demand set point. The available electricity is evenly distributed to each of the boilers that are operational. The electrical elements are activated in each boiler according to the load allowed from the master controller. These elements are activated on a first-on, first-off basis so that each is used consistently. The elements add to the total firing rate of the boiler and start to increase the pressure in the boiler.

The PID controller reacts to this increase in steam pressure by automatically reducing the gas rate until it reaches low fire. At some point, the electric load, plus the minimum gas firing rate increases the steam pressure past the steam operating pressure. This causes the gas to shut down and the boiler operates solely on electricity.

The master controller reads this situation and immediately routes all the available electricity to that boiler, in an effort to maintain the required steam pressure with electricity only. An internal routine in the programmable controller attempts to modulate the boiler with electricity and asks the master for an amount of the available power. If it is available, the master controller will provide it, split the rest between the other boilers. If the available only that amount is sent to the boilers. If the available electricity cannot maintain pressure the boiler steam pressure control will automatically restart the gas train to bring the pressure back to setpoint. The master control senses this and redistributes the electricity evenly to each operating boiler.

When the boilers are all operating with electricity, only the required electricity is used, thus the plant electric demand drops below the maximum control setpoint. At this point, the load factor drops from the maximum of 100% for the month.

6.0 System Installation Overview

The detailed system design was completed in the spring of 1985, allowing the boiler equipment to be purchased from Volcano Inc. Meetings were held between Bristol and Volcano to define how the control system would operate. In the summer of 1985, the three boilers were delivered to the Bristol Winnipeg Plant.

Four Seasons Ltd. was contracted to demolish one of the old boilers to make room for the new boiler. This proved to be an arduous task as the boiler had walls approximately six feet thick. Upon completion of the demolition, boiler #1 was lowered into place.

Kornovski and Keller were contracted to build the new boiler rooms within the plant space. These were completed in late summer and the remaining two boilers were put in place.

Delta Electric was contracted to provide and install the electrics that would be required to feed the boiler. Since the boilers did not increase the total electric demand of the plant, the new fired system did not require additional transformers, only new switches and feeder cables. Remote locking switches are on each boiler to disengage the boiler feed switch so that it cannot be activated when someone is working on the boiler.

The modification of the existing steam piping to accommodate the new boilers was completed by Bristol maintenance staff and Four Seasons Ltd. This is the one area that proved more costly than expected as large steam headers had to be manufactured for each boiler to provide a more continuous flow of steam to the plant.

The mechanical and electrical installation of the boilers was completed in October 1985, allowing the boilers to operate using their gas train.

The boiler control system was purchased in the spring of 1985 to allow programming and testing to be completed in time for the heat season startup. The program proved more complicated than initially expected, and was loaded in January 1986. Online debugging was required until February 1986 when the system became fully operational. The control system has worked without problem since that time.

6.1 Post Installation Problems

After the boiler system was installed some problems arose, which required attention.

Steam Capacity

During periods of extreme cold (> - 25 C for a week) boiler #1 did not have sufficient capacity to meet the demands of the North half of the plant. The cause of the problem was identified as an undersized steam pipe which connects the North and South sides of the plant. This was an existing pipe which was incorporated into the new system as a cost-saving measure. Replacement with a larger pipe was considered, but it would have been expensive, as it would have required excavation of the tarmac - which would interrupt the aircraft repair and overhaul operation. During these cold spells, boiler #2 operates at about 80% and boiler #3 operates at about 40%. A simple solution to the problem has been to allocate all available electricity to boiler #1 during these periods of extreme cold, while boilers #2 & #3 operate on natural gas only.

To change the control system to achieve this, required modifying a few parameters which only took about 15 minutes work. The longest to-date, the system has ever had to operate with all the available electricity allocated to boiler #1 is for three weeks, during 1988. It is unlikely that any permanent modifications will be made as the solution described above is effective, simple and best of all, inexpensive.

Boiler Room Ventilation

When the two new boiler rooms were constructed to house boilers #2 and #3, forced ventilation was not included in the design. Shorly after start-up it was found that the physical environment in both boiler rooms was too hot for the employees to work. This problem was solved by installing thermostatically controlled ventilation systems to provide fresh outside air to the rooms. The total cost for installing the systems was approximately $4,996.00.

Totalized Metering

Shortly after the dual-fuel boiler system was installed, Bristol Aerospace purchased what was to become Bristol Bldg. #7, formerly Ray-O-Vac Limited. This 86,000 foot building has since been gutted, and completely renovated, turning it into a state of the art machining center. Part of these renovations included the installation of a separate electrical service with a pulse metering system, similiar to the one on the South side of the plant.

Manitoba Hydro calculates Bristol's demand and consumption charges by totalizing the two data cartridges off-set using a computer system. This resulted in the load for Bldg. #7 not being monitored by the boiler control system. To solve this required totalizing the pulse output from the two utility meters to provide a single pulsed output to the boiler control

system. This was accomplished by installing a Sentry model #1542 totalizer and a data communication cable between the two meters for a total cost of $4102.00. Manitoba Hydro personnel from the Metering Division were extremely helpful to Bristol's Plant Engineering Group in assisting with the location and installation of this equipment.

7.0 Energy Cost Adjustments

7.1 Building Number 7

The actual efficiency of the dual boiler system is difficult to ascertain because the Winnipeg Plant was expanded from its original size when the proposal was completed. In 1986 and additional 86,000 sq. feet of office and manufacturing space was incorportated by purchasing an adjacent property. A tunnel was installed in the summer of 1986 to allow free access between the buildings. Equipment was gradually moved into building #7 and it became fully operational in early 1988.

The electricity for the new building is metered through a totalizing meter located in Building #2 to produce a reading for the entire Plant (see totalizing meter). This meant that the total plant electric load had to be increased to cover the additional load of building #7.

The new building is heated by natural gas in the manufacturing area and by a ground water source heat pump in the office space. The heatpump uses electricity to transfer heat to or from ground-ducts as required. The heatpump and groundwater pump run at variable rates on a 24 hour basis that is difficult to determine. It was calculated that 60 kVA was used on a 24 hour basis to heat and cool the new building. Since the boiler demand setpoints were not adjusted for this usage, the effective electricity available to the boilers was reduced and the heat generated by the boilers had to be replaced by natural gas.

A large number of machines were moved into building #7 from the older complex. These, along with the addition of some new machines have produced a new modern machining department. The heat generated by the estimated 280 kVA (40% utilization of 700 kVA) daily load served to reduce the heating load of building #7. This heat had to be replaced by the boilers in the old complex by using natural gas because the total electrical demand caused by moving the machines remained unchanged.

The electricity available to the boilers during the day was further reduced by the purchase of the new machines which insulated a further 60 kVA from the available demand. The lighting required also reduced the available electricity by a further 150 kVA.

The impact of building #7 was estimated as causing an additional electrical load of 2,250,000 kWh than would have been registered by the boiler system operating alone. The electrical demand is difficult to estimate, but by comparing the boiler setpoint to the actual demand, it is evident that the new total plant load exceeds the setpoint during the summer months. This means that the boilers must use more gas because there is never any available electricity.

The electrical effect of building #7 was calculated at $81,600. (see table B)

7.2 Heat Season Adjustment

The winter months of 1987 proved to be some of the warmest on record in Manitoba. This reduced the amount of heat that was required by the plant to maintain a working environment. This adjustment is never straightforward with a large complex like the Winnipeg plant because so much heat is generated by the use of machines. Also the heat generated by the moved machines had to be replaced. The heat season adjustment was calculated as increasing the bill to $733,043. (See Table C)

8.0 Boiler Performance

As shown by Table C, the normalized 1987 energy costs were calculated to be $733,043. This shows an energy saving of $69,660 when compared with a project energy cost of $802,703 that had been calculated for the proposal (Table D). This combined with the labor savings of $65,000 produces a total savings of $134,660 for the project.

The shortfall in the anticipated savings was calculated as $60,464 (See Table E). The majority of this additional cost comes from the fact that the system could not produce the 100% load factors that were predicted. In January 1987 the system did attain a 98% load factor. But by using the degree days alone to calculate the total heat required it does not account for fluctuations in the outside temperature. If there is a warm day during the month, the total plant heat requirement may fall below the total available off-peak electrical energy. Therefore the boilers will use less than the 100% load factor. Conversely, if there is a cold period, the boilers may use all available off-peak electrical energy, but more gas must be used to heat the plant. Therefore, the plant will always use less than the 100% load factor, and the extra heat required through the month must be replaced by more natural gas.

It also appears that the system used more gas during the summer months than anticipated. The effect of Building #7 is also present here, because the boilers had very little available electricity during the day when steam was required because of the demands of the new building. The steam for process equipment had to be produced by using more natural gas. The determination of the efficiency of the old boilers under new load may also have been low. It would appear that more process steam was delivered than anticipated, so this steam had to be produced by natural gas.

9.0 Economic Analysis

9.1 Capital Costs

Capital Costs	Estimated	Actual
3-200 HP D/F Boilers	248,700.00	348,751.13
Water treatment & Softening	28,980.00	75,391.36
Boiler Load Shedding Control	31,100.00	35,775.00
Condensate Lines	17,100.00	15,476.00
Air Line Relocation	15,150.00	6,261.00
Boiler Room Construction	45,550.00	31,797.98
Electrical Equipment	168,300.00	140,373.83
Engineering Costs	32,320.00	32,320.00
Total	593,900.00	697,305.30

9.2 Net Annual Savings

The Net Annual Savings are shown below:

Energy Saving	$ 69,660
Labor Savings	$ 65,000
Total Savings	$134,660

Note: Calculations are based on the data as provided in Tables A,B,C,D and E.
All calculations are based on 1987 Hydro and Natural Gas rates.

9.3 Simple Payback

Based on a total Bristol cost of $500,305 and a yearly saving of $134,660 the simple payback is 3.71 years.

The total project cost including funding assistance but excluding monitoring and information transfer costs totals $643,305 resulting in a simple payback of 4.77 years.

9.4 Maintenance Costs

The following chart shows the major maintenance costs for all 3 boilers from start-up to March, 1988. This list includes labour costs, where applicable, but does not include day-to-day normal maintenance such as; water treatment, safety checks, minor adjustments, etc.

Date	Maintenance Action	Approx. Cost
July/ 86	Replace baffle door refractory on all 3 boilers	Warranty
Aug/86	Replace 2 PLC output Modules boiler #2	640
Apr/87	Repair 2 boiler feed Pump Motors	Warranty
Jun/87	Replace boiler #3 blower motor bearings	220
Jul/87	Replace boiler #1 blower motor bearings	220
Aug/87	Repair baffle door refractory boiler #1 and #3	339

Aug/87	Replace baffle door refractory Boiler #2	Warranty
Aug/87	Rebuild contactors boiler #1	Warranty
Sept/87	Replace boiler #2 gas piping regulator and solenoid valve	829
Oct/87	Replace boiler #1 modulating gas valve	957
Nov/87	Repair boiler #1 chimney	2,367
Mar/88	Replacement of contactors fuse holders and element wiring required for boiler #1 (Estimated at $16,000.00)	Warranty

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Total estimated maintenance to date for all 3 Boilers	5,572.00

*Note: Approximate costs include labour cost where applicable.

10.0 Conclusions

The dual fired natural gas/electric boiler system installed at Bristol Aerospace Ltd. is providing energy savings at a slower rate than expected. The dual-fired boiler system is working well, however the addition of building #7 has impacted the system. With on-going monitoring and assessment, it is believed that the potential for additional system refinement and improvement exists.

Technically the project can be used in areas with a low load factor and a large process heat requirement. The cost effectiveness of replacing or modifying the current process heat source must be individually analysed.

The economic viability of the system hinges upon the rate structure for fuels. A drop in gas prices could make the system less viable because the demand free electrical heat cost could become greater than gas.

In any case, the system has provided Bristol with the ability to select the most economical fuel and to use renewable electricity instead of non renewable natural gas and oil.

Figures

A. Site Plan Bristol Aerospace Ltd. Winnipeg Plant

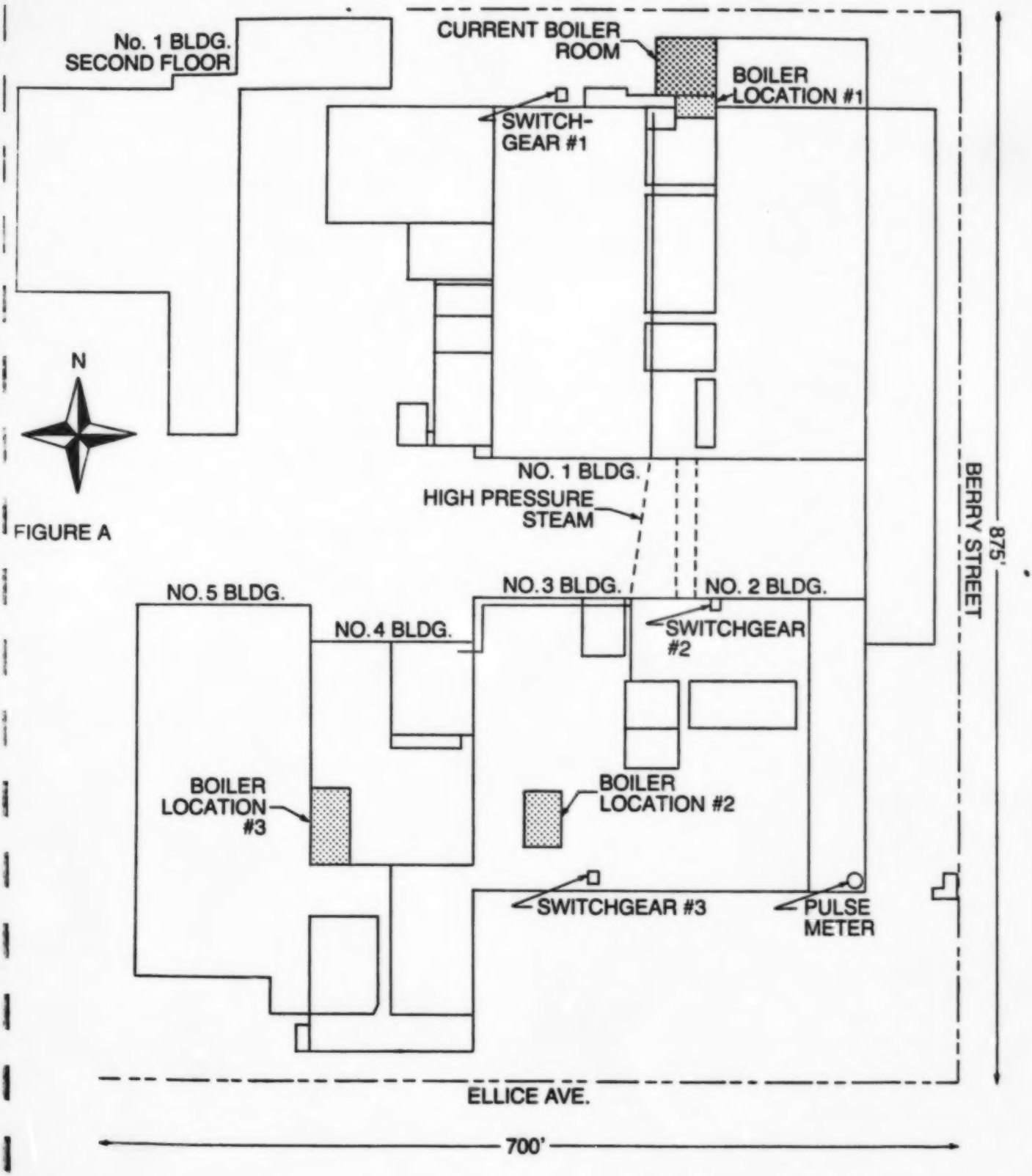
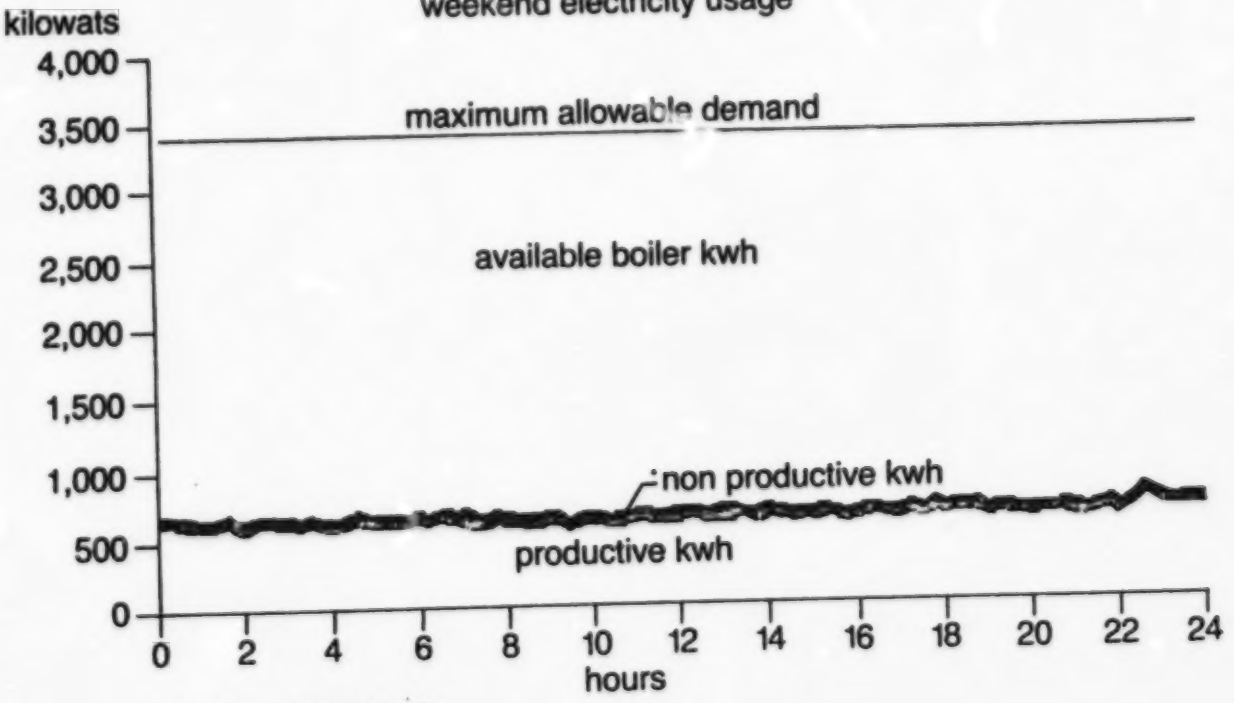


FIGURE A

figure b1

weekend electricity usage

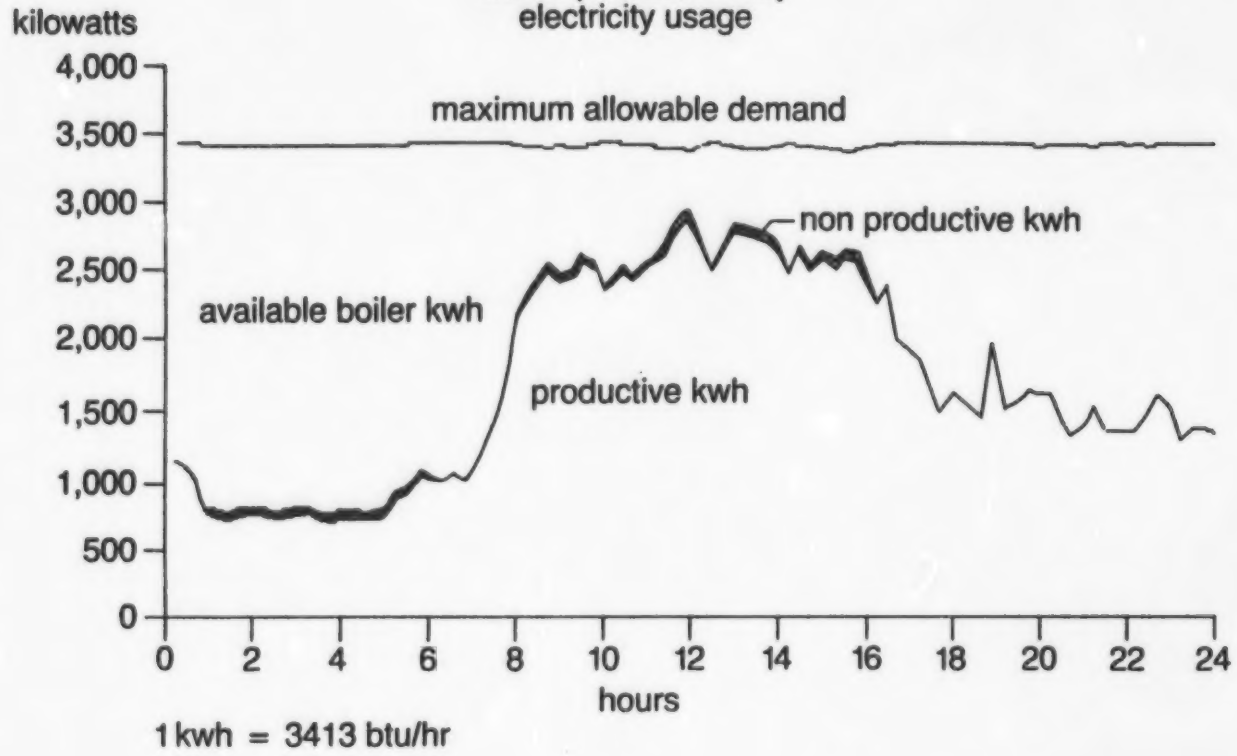


1 kwh = 3413 btu/hr

*non-productive process steam start-up time

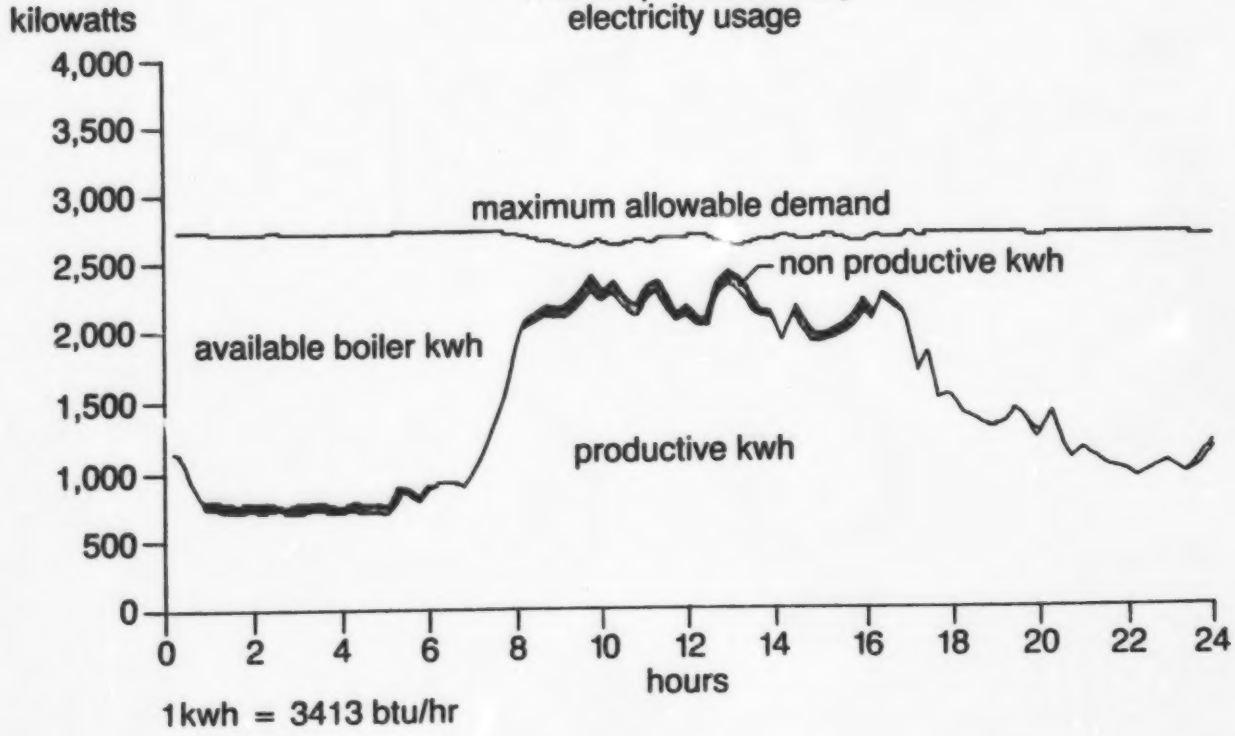
figure b2

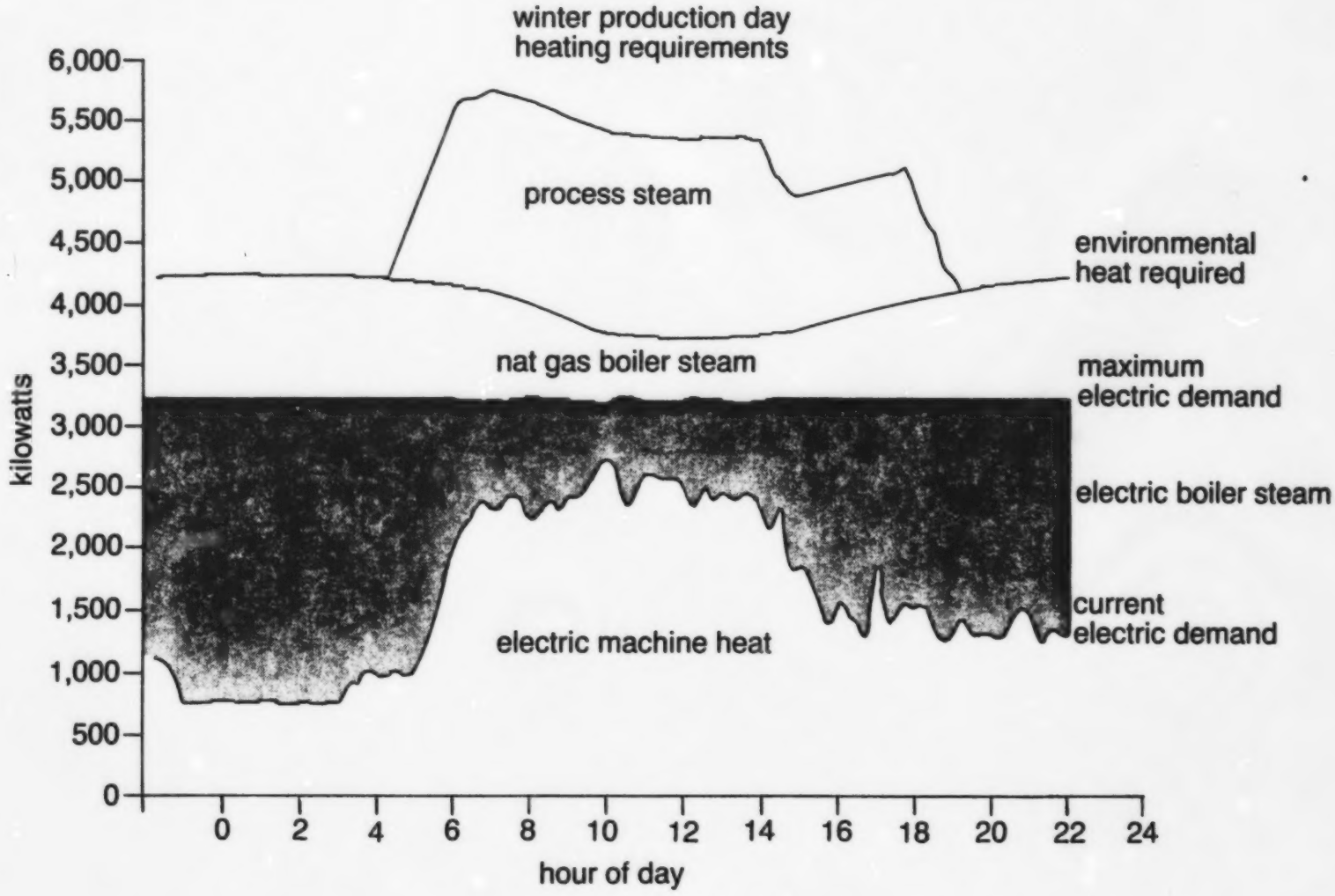
winter production day
electricity usage

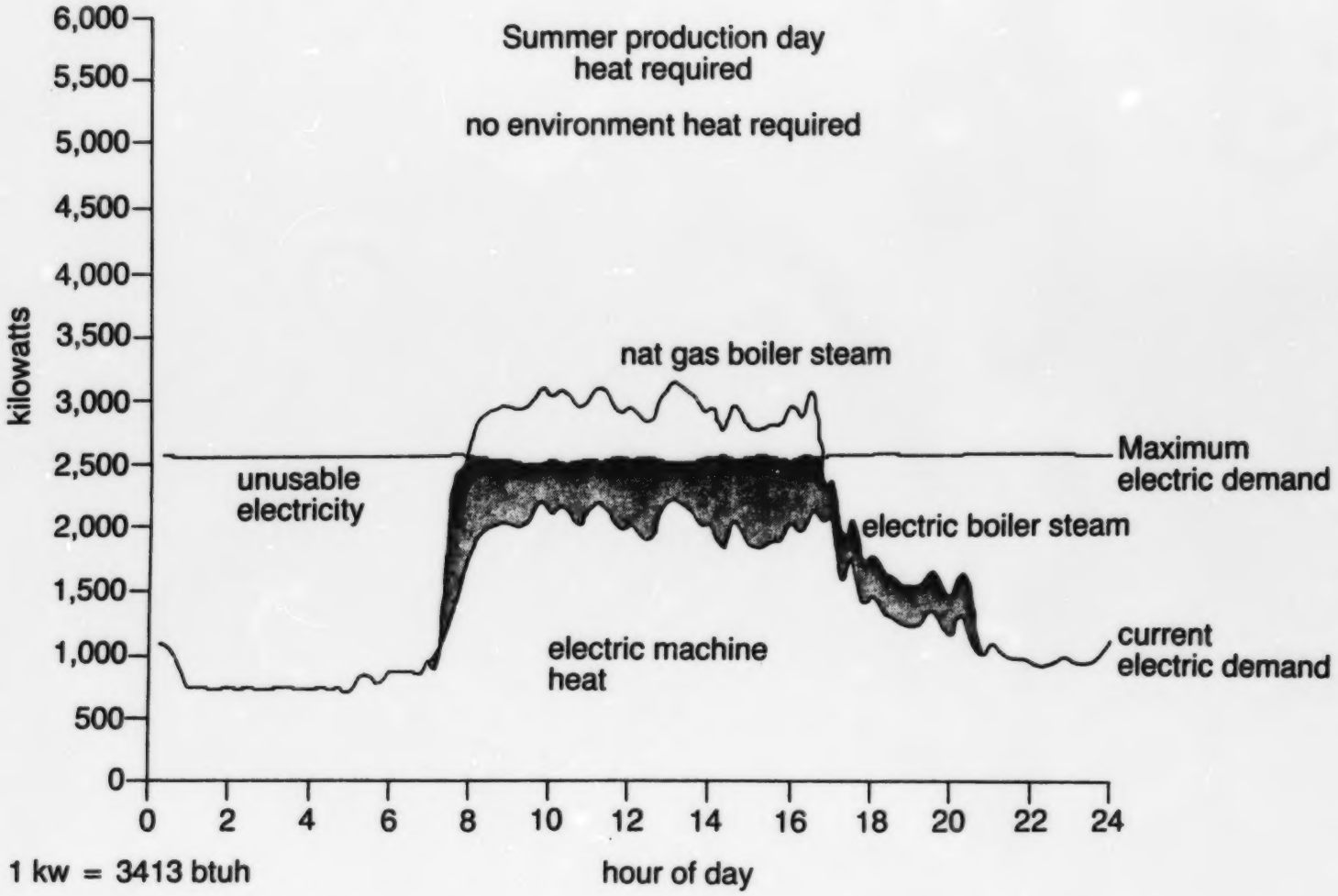


1 kwh = 3413 btu/hr

figure b3
summer production day
electricity usage




winter production day
heating requirements
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
kilowatts
process steam
environmental
heat required
nat gas boiler steam
maximum
electric demand
electric boiler steam
current
electric demand
electric machine heat
0
2
4
6
8
10
12
14
16
18
20
22
24
hour of day


Summer production day
heat required
no environment heat required
kilowatts
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
nat gas boiler steam
unusable
electricity
Maximum
electric demand
electric boiler steam
electric machine
heat
current
electric demand
0
2
4
6
8
10
12
14
16
18
20
22
24
1 kw = 3413 btuh
hour of day

Tables

TABLE A 1987 WINNIPEG PLANT ENERGY USAGE
— Inclusion of Building No. 7 Electricity Usage

MONTH	ELECTRICITY			NATURAL GAS		TOTAL COST
	kVA	kWh	COST	MCF	COST	
JAN	3687	2,509,894	$62,961	3844	$18,590	$ 81,551
FEB	3702	1,939,377	$53,694	6343	$30,100	$ 83,794
MAR	3603	2,367,935	$60,188	4789	$22,812	$ 83,000
APR	3330	1,931,917	$56,491	3373	$16,206	$ 72,697
MAY	3340	1,725,838	$53,353	1273	$ 6,373	$ 59,726
JUNE	3372	1,610,374	$51,525	940	$ 4,192	$ 55,717
JUL	3564	1,052,893	$42,716	1960	$ 8,530	$ 51,246
AUG	3288	1,432,984	$47,763	1138	$ 4,976	$ 52,739
SEPT	3388	1,554,947	$50,629	1094	$ 4,654	$ 55,283
OCT	3404	1,788,754	$54,961	1949	$ 7,947	$ 62,908
NOV	3339	2,091,889	$60,011	3087	$11,601	$ 71,612
DEC	3394	2,166,924	$61,737	5043	$18,643	$ 80,380
TOTAL:		22,173,726	$656,029	34,783	$154,624	$810,653

TABLE B 1987 WINNIPEG PLANT ENERGY USAGE

(Excluding Building No. 7)

	kVA	kWh	COST	BOILER GAS	COST	PROCESS GAS	COST	TOTAL COST
JAN	3350	2,320,990 93%	$57,730	3316	$16,036	1200	$5803	$ 79,569
FEB	3350	1,750,473 78%	$48,485	3572	$16,949	800	$3796	$ 69,230
MAR	3300	2,179,031 88%	$55,130	2816	$13,413	500	$3810	$ 72,353
APR	3000	1,743,013 81%	$47,894	2027	$ 9,885	300	$1463	$ 59,242
MAY	3000	1,536,934 69%	$47,113	1143	$ 5,721	302	$1511	$ 53,895
JUNE	2900	1,421,470 68%	$44,395	1416	$ 6,314	300	$1337	$ 52,046
JUL	2800	863,989 41%	$33,777	702	$ 3,055	300	$1306	$ 38,138
AUG	2800	1,244,080 60%	$40,570	889	$ 3,886	300	$1311	$ 45,767
SEP	2800	1,366,043 68%	$42,749	802	$ 3,411	300	$1276	$ 47,436
OCT	2950	1,599,850 73%	$47,910	4058	$16,544	500	$2038	$ 66,492
NOV	3050	1,902,985 87%	$53,982	3500	$13,153	800	$3006	$ 70,141
DEC	3150	1,978,020 84%	$55,978	3740	$13,826	1200	$4436	$ 74,240
		19,906,878	$575,713	27,981	$122,193	6802	$31,093	$728,999

TABLE C 1987 NORMALIZED WINNIPEG ENERGY USAGE

(Excluding Building 7)
(Adding move machine heat)

	kVA	kWh	COST	NORMAL DD	1987 DD	BOILER GAS	COST	PROCESS GAS	COST	TOTAL COST.
JAN	3350	2,320,990	$57,730	1993	1679	3718	$17,980	1200	$5803	$ 81,513
FEB	3350	1,750,473	$48,485	1714	1249	4683	$22,220	850	$4033	$ 74,738
MAR	3300	2,179,031	$55,130	1441	1285	2939	$13,998	376	$1790	$ 70,918
APR	3000	1,743,013	$47,894	810	514	2976	$14,513	285	$1389	$ 63,796
MAY	3000	1,536,934	$47,113	411	236	1143	$ 5,721	181	$ 906	$ 53,740
JUNE	2900	1,421,470	$44,395	147	79	1416	$ 6,314	195	$ 869	$ 51,578
JULY	2800	863,989	$33,777	37	35	702	$ 3,055	144	$ 626	$ 37,458
AUG	2800	1,244,080	$40,570	75	100	889	$ 3,886	113	$ 494	$ 44,950
SEPT	2800	1,366,043	$42,749	311	253	802	$ 3,411	184	$ 782	$ 46,942
OCT	2950	1,599,850	$47,910	686	829	3140	$12,801	250	$1019	$ 61,730
NOV	3050	1,902,985	$53,982	1255	1033	4034	$15,159	350	$1315	$ 70,456
DEC	3150	1,978,020	$55,978	1778	1460	4336	$16,030	870	$3216	$ 75,224
			$575,713			30,778	$135,088		$22,242	$733,043

TABLE D 1983 NORMAL YEAR ENERGY USAGE WITH 1987 COSTS
(Excluding Building No. 7)

MONTH	DEGREE DAY F	USAGE kWh	DEMAND kVA	COST	UNINTERRUPTIBLE NATURAL GAS MCF	COST ($)				
JAN	1993	914,000	3295	$34,599	1200	$5803	3980	$19,247	40,000	$52,000	$111,649
FEB	1714	872,000	3206	$34,095	850	$4033	8000	$37,960	15,000	$19,500	$95,588
MAR	1441	986,000	2987	$34,579	376	$1790	9125	$43,462			$79,831
APR	810	790,000	2745	$32,095	285	$1389	6820	$33,261			$66,745
MAY	411	823,500	2813	$33,139	181	$ 906	4030	$20,174			$54,219
JUNE	147	833,000	2695	$32,536	195	$ 869	3070	$13,689			$47,094
JULY	37	587,000	2745	$28,467	144	$ 626	1364	$ 5,936			$35,029
AUG	75	845,000	2805	$33,470	113	$ 494	2486	$10,868			$44,832
SEPT	311	811,500	2615	$31,628	184	$ 782	3350	$14,250			$46,660
OCT	686	802,000	2822	$32,813	250	$1019	5665	$23,096			$56,928
NOV	1255	924,000	3091	$36,755	350	$1315	8380	$31,492			$69,562
DEC	1788	890,000	3269	$37,313	870	$3216	9342	$34,537	15,000	$19,500	$94,566
		10,078,000		$401,489		$22,242		$287,972		$91,000	$802,703

TABLE E PROPOSAL COSTS WITH 1987 COSTS

MONTH	DEGREE DAY F	USAGE kWh	DEMAND kVA	COST	BOILER GAS	COST	PROCESS GAS	COST	TOTAL COST
JAN	1993	2,529,600	3400	$61,412	3305	$15,983	1200	$5803	$ 83,198
FEB	1714	2,284,800	3400	$57,444	3260	$15,468	850	$4033	$ 76,945
MAR	1441	2,232,000	3000	$54,187	1855	$ 9,026	376	$1790	$ 65,003
APR	810	1,603,600	2700	$46,340	1405	$ 6,852	285	$1389	$ 54,581
MAY	411	1,208,145	2700	$39,273	960	$ 4,805	181	$ 906	$ 44,984
JUNE	147	1,141,440	2700	$38,080	476	$ 2,122	195	$ 869	$ 41,071
JULY	37	787,200	2700	$30,678	199	$ 866	144	$ 626	$ 32,170
AUG	75	1,153,440	2700	$38,295	149	$ 651	113	$ 494	$ 39,440
SEP	311	1,186,740	2700	$38,890	573	$ 2,437	184	$ 782	$ 42,109
OCT	686	1,510,640	2700	$44,678	810	$ 3,302	250	$1019	$ 48,999
NOV	1255	2,160,000	3000	$58,248	1171	$ 4,400	350	$1315	$ 63,963
DEC	1778	2,529,600	3400	$67,473	2550	$ 9,427	870	$3216	$ 80,116
				$574,998		$75,339		$22,242	$672,579

TABLE F

BOILER PERSONNEL COST REDUCTIONS

MONTH	DAYS P DAYS W DAYS	NORMAL BOILER MONITORING HOURS PRODUCTION DAY	WEEKEND DAY	MONTHLY TOTAL	DUAL BOILER MONITORING HOURS PRODUCTION DAY	WEEKEND DAY	MONTHLY TOTAL
Jan	31/20/11	24	24	744	8	8	248
Feb	28/20/8	24	24	672	8	8	224
Mar	31/23/8	24	24	744	8	8	248
Apr	30/20/10	24	24	720	8	8	240
May	31/12/10	20	12	540	8	4	208
Jun	30/22/8	16	0	352	8	0	176
Jul	31/10/21	16	0	160	8	0	80
Aug	31/22/9	16	0	352	8	0	176
Sep	30/21/9	20	12	528	8	4	204
Oct	31/20/11	24	24	744	8	8	248
Nov	30/21/9	24	24	720	8	8	240
Dec	31/19/12	24	24	744	8	8	248
				7020			**2540**

SAVING = 7020 – 4480 HRS @ $14.50 = $64,960

(1987 dollars)